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Art. IV.—PASTEUR AND HIS DISCOVERIES.

1. *La vie de Pasteur.* Par René Vallery-Radot. Paris: Hachette, 1900.
2. *Pasteur.* By Percy Frankland and Mrs. Percy Frankland. (Century Science Series.) London : Cassell, 1898.
3. *The Soluble Ferments and Fermentation.* By J. Reynolds Green. (Cambridge Natural Science Manuals.) Cambridge University Press, 1899.
4. *Micro-organisms and Fermentation.* By Alfred Jörgensen. Translated by A. K. Miller and A. E. Lennholm. Third Edition. London: Macmillan, 1900.

As one walks down the Rue des Tanneurs, in the small provincial town of Dôle, where the main line from Paris to Pontarlier sends off a branch north-east towards Besançon, a small tablet set in the *façade* of a humble dwelling catches the eye. It bears the following inscription in gilt letters: 'Ici est né Louis Pasteur le 27 décembre 1822.'

Pasteur came of the people. In the heraldic meaning of the term, he was emphatically not 'born.' His forbears were shepherds, peasants, tillers of the earth, millers, and latterly, tanners. But he came from amongst the best peasantry in Europe, that peasantry which is still the backbone of the great French nation. The admirable care with which records are preserved in France has enabled Pasteur's son-in-law and latest biographer to trace the family name in the parish archives back to the beginning of the seventeenth century, at which period numerous Pasteurs were living in the villages round about the Priory of Mouthe, 'en pleine Franche-Comté.'

The first to emerge clearly from the confused cluster of possible ancestors is a certain Denis Pasteur, who became miller to the Comte d'Udressier, after whom he doubtless named his son Claude, born in 1683. Claude in his turn became a miller, and died in the year 1746. Of his eight children, the youngest, Claude-Etienne, was the great-grandfather of Louis Pasteur. The inhabitants of Franche-Comté were, in large part, serfs—'gens de mainmorte,' as they termed them then. Claude-Étienne, being a serf, at the age of thirty wished to enfranchise himself; and this he did in 1763, by the special grace of 'Messire

sentation of the character of Barabas in Marlowe's 'Jew of Malta,' and of that of Aaron in 'Titus Andronicus,' in both of which gigantic evil seems to be imitated merely for the sake of adding force to the dramatic representation. But he would not have disapproved of the part of Iago in 'Othello'; nor do we think that he would have acquiesced in Mr Butcher's conclusion that 'Satan, though he were never "less than archangel ruined," is not, under Aristotelian rules, a fitting character for an epic poem.'

It appears to us, on the contrary, that Aristotle would have recognised that, in 'Paradise Lost,' the poet was imitating an organic idea of nature, and that to the action of his poem the person of Satan was absolutely necessary. He would therefore have given it the praise which it undoubtedly deserves. The questions which he would have asked himself in judging any poetic imitation would have been, on the æsthetic side, whether the poem possessed a proper beginning, middle, and end; and on the moral side, whether this ideal imitation of Nature was calculated to produce sane and healthy pleasure of a kind which would be approved by a good citizen. There is no absolute æsthetic or literary standard by which a critic can determine whether a poem is good or bad in itself, nor can we in this matter go beyond the critical method of Aristotle. Let the modern critic, in appreciating a work of imagination, ask himself how far it answers to the idea of nature, viewed in the light of his own conscience and of the historic conscience of the society to which he belongs, and then see how far it is expressed in conformity with the laws proper to art. If he performs his functions in this spirit of reasoning independence, without fear or favour, he will be doing his part in the conflict with that literary anarchy which M. Recolin has described.

Philippe - Marie - Francois, Comte d'Udressier, Seigneur d'Écleux, Cramans, Lemuy, et autres lieux,' and on the payment of four *louis-d'or*. He subsequently married and had children. His third son, Jean-Henri, who for a time carried on his father's trade of tanner at Besançon, seems to have disappeared at the age of twenty-seven, leaving a small boy, Jean-Joseph Pasteur, born in 1791, who was brought up by his grandmother and his father's sister.

Caught in the close meshes of Napoleon's conscription, Jean-Joseph served in the Spanish campaign of 1812–13, as a private in the third regiment of infantry, called 'le brave parmi les braves.' In course of time he was promoted to be sergeant-major, and in March 1814 received the Cross of the Legion of Honour. Two months later the abdication had taken place; and the regiment was at Douai, reorganising under the name of 'Régiment Dauphin.' Here was no place for Jean-Joseph, devoted to the Imperial Eagle and unmoved by the Fleur-de-lys. He received his discharge, and made his way across country to his father's town, Besançon. At Besançon he took up his father's trade and became a tanner; and, after one feverish flush during the Hundred Days, and one contest, in which he came off victor, with the Royalist authorities, who would take his sword to arm the town police, he settled down into a quiet, law-abiding citizen, more occupied with domestic anxieties than with the fate of empires.

Hard by the tannery ran a stream, called La Furieuse, though it rarely justified its name. Across the stream dwelt a gardener named Roqui; amongst the gardener's daughters one Jeanne-Étiennette attracted the attention of, and was attracted by, this old campaigner of twenty-five years. The curious persistence of a family in one place, combined with the careful preservation of parish records, enables M. Vallery-Radot to trace the family Roqui back to the year 1555. We must content ourselves with Jeanne-Étiennette, who in 1815 married Jean-Joseph. Shortly afterwards the young couple moved to Dôle and set up house in the Rue des Tanneurs.

Louis Pasteur's father was a somewhat slow, reflective man; a little melancholic, not communicative; a man who lived an inner life, nourished doubtless on the memories of the part he had played on a larger stage than a tannery affords. His mother, on the other hand, was active in

business matters, hard-working, a woman of imagination, prompt in enthusiasm.

Before Louis Pasteur was two years old, his parents moved first to Marnoz and then to a tannery situated at the entrance to the village of Arbois; and it was Arbois that Pasteur regarded as his home, returning in later life year after year for the scanty absence from his laboratory that he annually allowed himself. Trained at the village school, he repeated with his father every evening the task of the day. He showed considerable talent, and his eagerness to learn was fostered by the interest taken in him by M. Romanet, principal of the College of Arbois. At sixteen he had exhausted the educational resources of the village; and, after much heart-searching and anxious deliberation, it was decided to send the young student to Paris to continue his studies at the Lycée Saint-Louis. It was a disastrous experiment. Removed so far from all he knew and loved, Louis suffered from an incurable home-sickness, which affected his health. His father hearing this came unannounced to Paris, and with the simple words 'Je viens te chercher' took him home. Here for a time he amused himself by sketching the portraits of neighbours and relatives, but his desire to learn was unquenched, and within a short time he entered as a student at the Royal College of Franche-Comté at Besançon. This picturesque town, situated only thirty miles from Arbois, was within easy reach of his home; and, above all, on market days his father came thither to sell his leather.

At eighteen Pasteur received the degree of Bachelier ès lettres, and almost immediately was occupied in teaching others; but Paris, although once abandoned, was again asserting its powers of attraction, and by the autumn of 1842 he was once more following the courses at the Lycée Saint-Louis. He also attended the brilliant lectures of Dumas at the Sorbonne, and vividly describes the scene: 'An audience of seven or eight hundred listeners, the too frequent applause, everything just like a theatre.' At the end of his first year in Paris he achieved his great ambition, and succeeded in entering the École Normale, and entering it with credit.

For the last year or two Pasteur had been studying mathematics and physics; at the École Normale he especi-

ally devoted himself to chemistry. Under the teaching of Dumas and of Balard his enthusiasm redoubled, and he passed his final examinations with distinction. Balard was indeed a true friend. Shortly after the end of his career at the École Normale, the Minister of Public Instruction nominated Pasteur to a small post as teacher of physics at the Lycée of Tournon. But banishment from Paris meant banishment from a laboratory. Balard intervened, interviewed the Minister, and ended by attaching Pasteur to his staff of assistants.

It must always be remembered that Pasteur was trained as a chemist, *was* in fact a chemist. In after life he attacked problems proper to the biologist, the physiologist, the physician, the manufacturer; but he brought to bear on these problems, not the intellect of one trained in the traditions of natural science, medicine, or commerce, but the untrammelled intelligence of a richly-endowed mind, 'organised common-sense' of the highest order. After the legal, there is perhaps no learned profession so dominated by tradition, by what our fathers have taught us, as the medical; and the advances in preventive medicine which will ever be connected with Pasteur's name owe at least something to the fact that he was unfettered by any traditions of professional training or etiquette. Passing from the diseases of the lowest of the fungi, to those of a caterpillar, a fowl, a sheep, until he reached those of man himself, it must be acknowledged that he approached the art of healing along an entirely new path.

His first researches were purely chemical, 'On the capacity for saturation of arsenious acid,' 'Studies on the arsenates of potassium, soda, and ammonia'; but he had been early attracted to the remarkable observations of Mitscherlich and others on the optical properties of the crystals of tartaric acid and its salts. Ordinary tartaric acid crystals, when dissolved in water, turn the plane of polarised light to the right; but another kind of tartaric acid, called by Gay-Lussac racemic acid, and by Berzelius paratartaric acid—as M. Vallery-Radot remarks, the name does not matter, and each is equally terrifying to the lay mind—leaves it unaffected. In spite of the different actions of the solutions of these two acids on light, Mitscherlich held their chemical composition to be absolutely identical.

This set Pasteur thinking. He repeated the experi-

ments. On examining the crystals of sodium-ammonium salt of racemic acid, he noticed that certain facets giving a degree of asymmetry were always found on the crystals of the optically active salts and acids. On examining the crystals of the racemic acid, he did not find, as he had expected, perfect symmetry, but he saw that, whilst some of the crystals showed these facets to the right, others showed them to the left. In fact, sodium-ammonium racemate consisted of a mixture of right-handed and left-handed crystals, which neutralised one another as regards the polarisation of light, and were thus optically inactive. With infinite patience Pasteur picked out the right- from the left-handed crystals, and investigated the action of their solutions on polarised light. As he expected, the one sort turned the plane of polarisation to the left, the other to the right. A mixture of equal weights of the two kinds of crystals remained optically inactive. 'Tout est trouvé,' he exclaimed; and rushing from the laboratory, embraced the first man he came across. 'C'était un peu comme Archimède,' as his biographer gravely remarks.

His work immediately attracted attention. Biot, who had devoted a long and strenuous life to the problems of polarisation, was at first sceptical, but after a careful investigation was convinced. Pasteur began to be talked about in the circle of the Institute.

In the midst of these researches, Pasteur's mother died suddenly, and her son, overwhelmed with grief, remained for weeks almost silent and unable to work. Shortly after this we find the old longing revived; and Pasteur sought at any cost some post near Arbois, somewhere not quite out of the reach of those he loved. Besançon was refused him, but at the beginning of 1849 he replaced M. Persoz as Professor of Chemistry at Strasbourg.

The newly appointed Rector of the Academy of Strasbourg, M. Laurent, had already gained the respect and the affection of the professoriate. He and his family were the centre of the intellectual life of the town. Within a few weeks of his arrival, Pasteur addressed to the Rector a letter, setting forth in simple detail his worldly position and asking the hand of his daughter Marie in marriage. The wedding took place on the 29th May, 1850; and there is a tradition that Pasteur, immersed in some chemical experiment, had to be fetched from the laboratory to take

his part in the ceremony at the church. Never was a union more happy; from the first, Madame Pasteur—animated by the spirit of the Academy of Science, which always prints 'Science' with a capital letter—not only admitted, but approved the principle that nothing should interfere with the laboratory; whilst, on his side, Pasteur always flew to his wife to confide in her, first of all, any new discovery, any new advance he had made in his researches. During the five years passed at Strasbourg, Pasteur continued to work on the border-line between chemistry and physics. His work on the polarisation of light of the tartaric acid crystals led him into the question of the arrangement of the atoms within the molecule. 'Il éclaire tout ce qu'il touche,' exclaimed the once sceptical but now convinced Biot; and it is hardly too much to say that his researches were the starting point of the new department of physics which, under the name of stereo-chemistry, has attained vast developments during the last quarter of the past century. These researches were rewarded by the French Government, which in 1853 conferred on him the ribbon of the Legion of Honour; and received the recognition of our own Royal Society, which awarded him in 1856 the Rumford medal.

It was whilst working at his beloved tartrates that he made an observation which first directed his attention towards the problems of fermentation. A German firm of manufacturing chemists, of whom there were many in the neighbourhood of Strasbourg, noticed that impure commercial tartrates of lime, when in contact with organic matter, fermented if the weather were warm. Pasteur tested this, and found that when racemic acid is fermented under ordinary conditions, it is only the right-handed variety that is affected; and he suggests that this is probably the best way in which to prepare the left-handed acid.

Before dealing with Pasteur's work on fermentation, it is well to recall how the matter stood when he began to study it. From the earliest period fermentation had attracted the attention of mankind, but the first record of an attempted explanation is that of Basilius Valentinus, a Benedictine monk and alchemist, who lived at Erfurt during the latter half of the fifteenth century. He was, perhaps, more of a pharmacologist than a chemist; but we

owe to him the introduction of hydrochloric acid, which he made from oil of vitriol and salt. In his view, alcohol existed in the wort before fermentation began; and fermentation was a process of purification of this alcohol, in which the yeast played the part of the impurities. About a century later van Helmont, a well-to-do physician of Vilvorde, near Brussels, a kind of regenerate Paracelsus, noted that when fermentation occurs, 'gas' is set free. It was van Helmont indeed who invented the word 'gas.' Of the half-dozen words invented by man—not derived but created—'gas' is the one which has most surely come to stay. Curiously enough, van Helmont's predecessor, Paracelsus, also invented two words which have, without the permanency of 'gas,' passed into current though somewhat infrequent use. They are 'gnome' and 'sylph,' the latter perhaps best known as recalling the outline of Mrs Crummles in her palmier days. By his new term 'gas,' van Helmont did not mean an air or vapour, still less did he mean an illuminant. He understood by this term carbon dioxide, and he points out that, when sugary solutions ferment, this gas is given off.

About 1700 Stahl, returning to a view put forward by Willis in 1659, propounded the first physical view of fermentation. The ferment was to their minds a body with a certain internal motion which it transmitted to the fermentable matter. Stahl extended this view to the processes of putrefaction and decay. One hundred years later Gay-Lussac taught that the fermentation was set up by the presence of oxygen. The yeast-cells had been seen and described by Leeuwenhoek as far back as 1675, but they seem to have attracted little attention; and it was not until Schwann published his researches, the earliest of which is dated 1837, and until Cagniard de Latour, about the same date, put forward his vitalistic theory—the theory which attributes fermentation to the action of living organisms—that they were recognised as playing an important part in fermentations. Even then they were not allowed to hold the field. Liebig brought the weight of his great authority to oppose the vitalistic theory. In his view, the ferment was an unstable organic compound easily decomposed, which in decomposing shook apart the molecules of the fermenting material. This theory and that of Berzelius, who regarded fermentation as a contact

action due to some 'catalytic' force, divided between them the allegiance of the chemical world when, in the year 1854, Pasteur was nominated Professor and Dean of the new Faculty of Science at Lille.

Here, in the centre of the beet-root industry, Pasteur had ample opportunity to study the preparation of alcohol. The father of one of his students owned a distillery, and suffered occasional loss from the fermentations turning sour owing to the formation of lactic acid. He was willing to place material at the disposal of the Professor; and Pasteur made endless experiments, microscopic researches, notes, and at length had the satisfaction of isolating the organism which produces the lactic acid fermentation, and of proving that that, and that alone, was capable of setting up this particular form of fermentation. Whilst in the middle of his investigations on milk and the cause of its turning sour, Pasteur was summoned to return to Paris, and installed as scientific Director at his old college, the École Normale.

This was in 1857. The second Empire was at its zenith, and the Government had little money to spend on science. Pasteur had to instal his laboratory in a garret, without even a boy to aid him. In this garret he completed his work on alcohol fermentation, proved it to be 'un acte corrélatif d'un phénomène vital, d'une organisation de globules.' During this work he noted a fact hitherto overlooked. It was that the alcoholic fermentation is accompanied by the formation of small quantities of glycerine and of succinic acid, which had up till that date escaped the notice of chemists.

During the seven years which followed, Pasteur was ceaselessly engaged in investigations on fermentation and on all those processes for which micro-organisms are responsible. Whilst researching on the cause of butyric acid formation, he discovered the remarkable fact that the *Bacillus butyricus*, which causes the unpleasant flavour in rancid butter, will not grow in the presence of free oxygen. Until this discovery it had been accepted as an axiom that all living beings, plants as well as animals, require free oxygen for the manifestation of their energies. Here, however, was a bacillus which not only did without oxygen but was injured by its presence. This observation, it is needless to remark, excited much adverse criticism in the

scientific world; but, as usual, Pasteur was in the right. From the conditions under which they grow he suggested the name 'anaërobic' for such bacteria as *B. butyricus;* and later observers have shown that many pathogenic micro-organisms are anaërobic. At the present day bacilli are usually divided into two groups, those which grow in the presence of free oxygen (aërobic), and those which will not grow in the presence of oxygen (anaërobic).

Naturally the question of spontaneous generation occupied much of Pasteur's time. The view, that in certain circumstances living matter originates from non-living, lasted from the classical times until towards the end of the last century. The size of the animal so produced varied, however, inversely with the growth of our era. Van Helmont in the seventeenth century had a recipe for producing mice. Place a piece of linen somewhat soiled in a vessel, add some grains of corn, flavour with a piece of cheese, and in twenty-one days the mice will be there, fully adult and of both sexes.

About the time that van Helmont died there was coming to the front in Florence a young Italian poet, born at Arezzo—in whose cathedral he now lies buried—who had a singular turn for investigating the secret workings of organic nature. Francesco Redi—his name is immortalised in the little larva Redia—was courtier, poet, doctor, above all zoologist; and he belonged to that comparatively small section of teetotallers who have enthusiastically sung the merits of wine.* By a series of accurate experiments, such as nowadays are performed by every cook, Redi proved conclusively that meat did not spontaneously produce flies. Shortly afterwards Vallisnieri of Padua demonstrated that fruit did not of itself give rise to grubs. In fact, unless an insect deposited its egg in the fruit, there were no grubs.

The use of the microscope, however, lent a fresh vigour to the believers in spontaneous generation; and, forced to relinquish the mouse and the insect, they still found satis-

* A volume of Redi's poems, entitled 'Bacco in Toscano,' was published in 1804. Longfellow says of him :—

> 'Even Redi, when he chanted
> Bacchus in the Tuscan valleys,
> Never drank the wine he vaunted
> In his dithyrambic sallies.'

faction in germs. In the middle of the eighteenth century the doctrine was firmly upheld by an English priest, one Needham, whose experiments, in spite of the keen, and as as we now know, unanswerable criticisms of the Abbé Spallanzani, were so convincing that he was early elected a Fellow of the Royal Society. From his time till late in the last century, the question of the spontaneous origin of microscopic life has from time to time troubled the mind of man. Pasteur, Tyndall, and others have at length laid that ghost. It would take too much space to discuss all the experiments made to solve this question. Pasteur's work did not escape the liveliest criticism; and eventually, in order to settle the matter, he appealed to the Academy of Sciences to appoint a Commission to report on the experiments of himself and his opponents. It is needless to say that when the Committee met and inspected the experiments of Pasteur, and listened to the excuses of his critics, they pronounced absolutely in favour of Pasteur.

In 1862 Pasteur succeeded Senarmont as a member of the Academy of Sciences; and, it is interesting to note, he was presented by the mineralogical section. During this year he had interested himself in the manufacture of vinegar, which is extensively carried on in and around Orleans. He investigated the action of the *Mycoderma aceti*, the mould whose activity converts alcohol into acetic acid; and he taught the manufacturers the importance of pure cultures, showing them how, by a careful manipulation of the temperature, and by artificially sowing the fungus which effects the chemical change, the product they sought could be produced in a week or ten days, instead of requiring two or three months. This problem naturally led on to the acetous fermentation of wine, the cause of great loss to French wine exporters. Pasteur was able to demonstrate that the sourness of wine is caused by various foreign organisms, each of which causes a peculiar flavour to appear in the wine it attacks. The bouquet of wine is notoriously a delicate object, easily disturbed; and the question arose how to check the growth of the organisms without interfering with the bouquet. Pasteur solved it as he solved similar problems with regard to milk. He was able to show that after wine is properly oxygenated, if it be heated to a temperature of some 55° to 60° C. the acid-forming micro-

organisms are destroyed, whilst the bouquet is unaffected. Perhaps one of Pasteur's greatest triumphs was his success in demonstrating this to a representative assemblage of wine-tasters, notoriously a very opinionative class of people.

Pasteur's researches on micro-organisms further had a profound influence on operative surgery. To the presence of bacteria is due many of the dangers which used to follow on operations. If precautions are taken to exclude the harmful germs much suffering and danger are avoided. It was about this date, namely, in the spring of 1865, that Dr (now Lord) Lister, who nobly acknowledged the debt he owed to Pasteur, performed his first operations under anti-septic treatment at the Glasgow Infirmary. This date marks an epoch in the history of human suffering.

The chemist Dumas was about this time a member of the French Senate, and in 1865 was charged with the duty of reporting on the petition of some three thousand five hundred 'propriétaires des Départements séricicoles' on an epidemic which had for some years been destroying the silkworms of southern France. Dumas was a native of Alais, a town of the Département Gard, situated in the centre of the silkworm industry, where also the distinguished zoologist Quatrefages was born. Anything that affected Alais affected Dumas; and the epidemic was destroying the prosperity of his native town. The disease was indeed becoming serious. Already in 1849 the silkworms were sickening. The stage at which the symptoms appeared varied; sometimes the eggs were sterile; at other times the silkworms hatched out but to die. If they survived they became shiny; black spots showed themselves; the worms moved with difficulty, refused to eat, and perished; or, if they lived long enough to pupate, the pupa perished or the moth emerged in an enfeebled state and promptly died.

Efforts had been made to improve the stock by importing eggs from Spain and Portugal, but the Peninsula was soon affected. Eggs were then fetched from Turkey, Greece, and the adjacent islands. These countries too becoming infected, the French cultivators sent further afield and brought eggs from Syria and the Caucasus. Even this resource failed them, and in 1864 every silk-producing country in the world was infected, with the solitary ex-

ception of Japan. The loss to commerce was prodigious. In a normal year the value of the cocoons produced in southern France is, roughly speaking, about 4,000,000*l.*; in the years 1863 and 1864 it had fallen below 1,000,000*l.*

When Dumas first asked Pasteur to investigate the disease which was ruining large tracts of the south of France, the latter not unnaturally hesitated. 'Considérez, je vous prie, que je n'ai jamais touché un ver à soie. Si j'avais une partie de vos connaissances sur le sujet, je n'hésiterais pas'—he wrote to his friend; but in spite of his hesitation, he left for Alais and at once commenced a campaign which lasted during the summers of the next five years. Almost immediately on his arrival he detected in the sick silkworms the corpuscles of Cornalia and Filippi which we now call the *Micrococcus ovatus.* These micrococci are comparatively large and very bright; they occur in the tissues and blood of the silkworm, and are found even in the eggs of the moth. They cause the disease known as Pébrine. The occurrence of the micrococci in the eggs was one of the most important new facts observed by Pasteur. It was the first recorded instance of a parasitic organism being conveyed from one generation to another by the egg; and, although quite recently the germ of the Texas fever (allied to the malarial organism) has been shown to pass from one brood to another through the egg of the tick which conveys it, it is satisfactory to record that the cases in which this occurs are restricted in number and comparatively rare. The ease with which *Micrococcus ovatus* could be detected suggested a remedy. A child, when trained, can readily identify the organism. Healthy moths produce sound eggs and healthy larvæ; diseased moths produce diseased progeny. At the present day, throughout the silkworm districts of the south of France, as soon as the moth has deposited her eggs on the piece of linen provided for that purpose, she is pinned up with the cloth; and during the ensuing autumn and winter the women and children are occupied in microscopically examining the body of the moth, crushed in a little water, for traces of the micrococcus. Should any be found, the eggs on the corresponding piece of linen are at once destroyed. Pasteur also showed that the infected stock spread the disease by distributing the micrococci on the mulberry

leaves, whence they enter the silkworm by the mouth; and that the sick inoculate the healthy by crawling over them and piercing the skin with their pointed claws. He therefore emphasised the importance of segregating the sound caterpillars.

The above account conveys no impression of the difficulties under which Pasteur worked. His researches were not only new to himself but to the world. Processes which at the present day are carried out by every medical student had to be devised for the first time. He had to combat the criticism of scientific men and to overcome the almost invincible ignorance of the agriculturist, an ignorance which at one time advocated the desperate remedy of asperging with absinthe the leaves of the mulberry on which the silkworms fed.

Perhaps Pasteur's greatest difficulty was the fact that the silkworms did not suffer from Pébrine alone; and it was some time before he recognised that he had to deal not with one disease but with two. The second disease, known as the 'Flacherie,' is a disease of the digestive system caused by overcrowding and insanitary conditions in the silkworm nurseries. Like Pébrine, it is caused by a micrococcus, *M. bombycis*. It was whilst investigating this creature that Pasteur discovered that, although the germ itself cannot survive a lengthy period of desiccation, it does in certain circumstances form spores which can survive conditions fatal to the mature organism. This is the first case recorded of a pathogenic organism producing spores, the existence of which has explained so many problems in the spread of disease.

During the period from 1865 to 1870 Pasteur was by no means occupied solely by the silkworm epidemic. In many respects it was a sad epoch in his life. Only nine days after his first arrival at Alais he was summoned to Arbois to see his dying father, but arrived too late. In the autumn of the same year he lost his little daughter, Camille, the second who had died. In 1868 he himself was prostrated by a stroke of paralysis, and, although he slowly recovered, it left traces for the remainder of his life.

Few distinguished men of science are left to pursue their investigations undisturbed; and Pasteur was no exception. He had much to do with promoting the publication of the works of Lavoisier, for whose researches

he had the profoundest respect. He actively intervened in the elections of the Academy of Science, which appears to consume an infinity of time. He made some preliminary investigations into cholera, an outbreak of which towards the end of the year 1865 carried off two hundred victims a day in Paris. He spent a week at Compiègne as the guest of Louis Napoleon, and in a series of *séances* explained the methods and results of his labours. He wrote on the work of Claude Bernard ; he drew up schemes for certain reforms in the University; he gave advice on the higher education of the country, and tried to stem the troubles of the École Normale. In fact he drew lavishly upon his reserve of health and energy until the breakdown of 1868 was inevitable.

After a tedious recovery he recommenced his work. The success of his methods had been acknowledged by the Austrian Government, which conferred on him in 1868 the prize of five thousand florins offered to anyone who should succeed in discovering the best means of dealing with Pébrine. The same year the University of Bonn conferred on him the honorary degree of Doctor of Medicine; and in 1869 he was elected a foreign member of the Royal Society. As was to be expected, detractors were not wanting; but these were silenced by the campaign undertaken in 1869 by Pasteur on foreign soil. The Master of the Imperial Household, Marshal Vaillant, who devoted his declining years to scientific experiments, had repeated in his apartments in the Tuileries the observations of Pasteur on the silkworm disease, and had verified the accuracy of his conclusions. He suggested to the Emperor that the Villa Vicentina, a property belonging to the Prince Imperial, should be placed at Pasteur's disposal for further research. This villa, situated a few miles from Trieste, belonged at one time to the Princess Élise, one of the sisters of Napoleon I, who had lived quietly there after the fall of the first Empire. On her death it passed to her daughter the Princess Baciocchi, and she in turn bequeathed it to the Prince Imperial. It had been a great centre of the silkworm industry; but for some years no cocoons had been produced, owing to the ravages of the disease.

By short stages, owing to his precarious health, Pasteur made his way to Illyria, taking with him some sound

silk-moth eggs, and during the winter not only confirmed his previous researches, but re-established the industry on such a scale that in the following spring the sale of cocoons from this estate alone reached the figure of 26,940 francs. During this winter he dictated to his wife the classic book in which he recorded the results of his last five years' work. Pasteur returned to Paris through Munich, where he had the pleasure of meeting Liebig, one of the most determined of his adversaries. Although he was unable to induce the German savant to discuss scientific affairs, he always dwelt with pleasure on the courtesy and cordiality with which he was received.

On his return the Emperor nominated him a Senator for life; but, before the gazette appeared in which the nomination would have been recorded, war was declared. From his birth Pasteur had been an ardent patriot, and during the progress of the war he suffered acutely. So much did he feel the reverses of his country, and what he regarded as the undue harshness of the victors, that he felt constrained to return the diploma of Doctor of Medicine which two years before he had accepted from the University of Bonn. He did so in a letter which contained some expressions of feeling with regard to the head of the invading army. These had better have been omitted, but were perhaps pardonable under the circumstances; they in no way excuse the terms of reply which Dr Naumann, Dean of the Faculty of Medicine at Bonn, permitted himself to use—terms which would be discreditable in an ill-bred street *gamin*.

From 1871 to 1876, the year in which he published his 'Études sur la Bière,' Pasteur was again largely occupied with the study of fermentation. Part of his object was undoubtedly to place the French brewers on an equality with the German; and in this he certainly had a large measure of success. To one who knew Paris under the second Empire and who revisits it under the third Republic, one of the first changes observable in the life of the *café* is the enormous consumption of 'bocks.' Pasteur's work, however, went far beyond the establishment of a national industry. He started investigations which have changed brewing from an art into a science; and his most fitting memorial in this respect is the bust which decorates the hall of the Carlsberg Institution at Copenhagen, an insti-

tution devoted to the study of all problems of fermentation. In his 'Études,' Pasteur laid great stress on the fact that every fermentation is brought about by micro-organisms, and he dwells at length on the marked influence which certain bacteria exercise on the nature of the fermentations, and on the character of the beer produced. He did not however see, what Hansen demonstrated in 1883, that many of the commonest diseases of beer are caused by certain species of yeast-cell differing specifically from those which cause its normal fermentation. Indeed, he paid but small attention to species, regarding it as waste of time, as it undoubtedly often is, to trouble about names and synonyms.

As Professor Jörgensen and Dr Green show in the two works whose titles appear at the beginning of this article, we have learnt much about brewing during the last five-and-twenty years. The nucleus of the yeast-cell has been made visible by appropriate staining; some thirty different species of yeast-cell have been described, and their properties as ferments have been investigated; Buchner, by grinding up the yeast-cells, has produced an extract, called zymase, capable of converting sugar into alcohol; the fact has been established that it is not so much bacteria as other fungi, allied and often congeneric with the yeast-cell, which produce disease in beer; still, allowing a full measure of credit to later workers, we may look back to Pasteur's researches in the early seventies as establishing for the first time a scientific basis for brewing.

The same remarks are applicable to Pasteur's work on the diseases due to specific organisms in the region of preventive medicine. We have built and are building a lordly edifice, but he drew the plan and even laid the foundations. More than two centuries ago Robert Boyle—'the Father of Chemistry and Brother of the Earl of Cork'—had said that he who could solve the nature of fermentations would be without doubt more capable than others of explaining certain phenomena of disease. Towards the end of his 'Études sur la Bière' Pasteur wrote: 'The ætiology of contagious diseases is on the eve of having unexpected light shed upon it.' He was already thinking of his investigations into the cause and prevention of contagious disease.

There is a certain malady known, when it attacks

cattle and sheep, as 'charbon' or 'sang de rate,' and when it attacks man, as 'wool-sorters' disease.' The term Anthrax covers the disease in both beast and man; and anthrax is produced by a bacterium known as *Bacillus anthracis*, which had been recognised and was accused of causing the disease before Pasteur began to interest himself in such matters. It annually carried off twenty per cent. of the sheep in the agricultural district of La Beauce; and in Auvergne some ten to fifteen per cent. In certain localities the loss was greater, amounting at times to an annual death-rate of fifty per cent. The disease was by no means confined to France; it was spread over Europe. In the government of Novgorod it was responsible for over fifty-six thousand deaths in three years. In Egypt it was regarded as the direct descendant of the plagues of Pharaoh. It ravaged the large sheep farms of the Argentine Republic.

The bacillus which causes this disease, and which at times by inhalation effects a lodgment in the bodies of those engaged in handling wool and hides, was already known when Pasteur took up the study of pathogenic germs. About the same time it was also attracting the attention of the young German physician Dr Koch, who subsequently became a severe critic of some of Pasteur's work; but in this article we are dealing with Pasteur, and limitations of space compel us to leave unnoticed the brilliant work of many investigators who have made the latter end of the nineteenth century one of the greatest epochs in medical history.

Pasteur and his assistants made many fascinating studies on the behaviour and life-history of the *Bacillus anthracis*. He found it very susceptible to slight variations of temperature. The few degrees by which the temperature of a bird's blood exceeds that of a mammal were sufficient to prove fatal to the bacillus; but by an ingenious experiment he showed that if the temperature of a bird be artificially lowered it becomes susceptible to the disease, though it readily recovers if the artificial surroundings be removed. Pasteur further noted that the bacillus was not equally fatal in all animals, and that it changed its character when passed through the body of certain classes of animals. It was, however, not in studying the *Bacillus anthracis* that he made the far-reaching

discovery of the attenuated virus. This he first noted when at work on chicken-cholera, a disease very fatal in poultry yards; and he made the important discovery by one of those happy accidents which only occur to those who possess the genius for observation. During his numerous experiments he one day chanced to inoculate some fowls with a forgotten culture some weeks old. To his surprise the chickens, though made ill, did not succumb; in fact they rapidly recovered. He immediately tried what the effect would be if these same fowls were inoculated with fresh cultures of a kind so powerful as to be undoubtedly fatal to a healthy bird which had never suffered from the disease. To his delight the inoculated fowls resisted the poison and proved in fact immune. This simple experiment is the basis of the world-wide prophylactic measures which are now being carried on against almost all forms of bacterial disease; and, although Pasteur's explanation of the weakening of the virus—which he attributed to oxygenation—has been shown to be erroneous, he must still be regarded as the originator of methods for the production of immunity by means of artificially attenuated organisms.

If the virus of chicken-cholera can be attenuated, and when attenuated produces immunity from later attacks, the same is probably true of other germs which can be cultivated outside the body. Arguing in this fashion Pasteur returned to his study of anthrax. Here he also succeeded, and in the spring of 1881 he demonstrated the value of his treatment. Out of a flock of fifty sheep one half were inoculated, the other half were not; the whole flock was then infected with the disease. In less than a month the uninoculated were dead of *charbon*, the inoculated were perfectly healthy. The telegram announcing the result to Pasteur, anxiously waiting in his laboratory at Paris, ended with the words 'Succès épatant!'

So striking a demonstration naturally had a profound effect. It inspired confidence in the treatment. Since the date of this experiment some millions of sheep have been inoculated against anthrax, and several hundred thousand oxen; and it has been calculated that, within the succeeding twelve years, seven million francs were saved by this means alone to French agriculture. Perhaps the convincing nature of Pasteur's work in this connexion is best shown by the fact that the insurance companies of France

insist on inoculation before they will insure sheep and cattle.

We have left ourselves but little space to dwell on the work which occupied the greater part of the last twelve years of Pasteur's life. Already, in the midst of his work on anthrax, he was thinking of rabies; and in 1881 he proved that it was conveyed through the saliva of the mad dog, and that it could be communicated to rabbits. Saliva, however, was not in every case to be depended on. In some cases it failed to convey the disease. Experiment showed that the poison was concentrated in the brain. To this day no one has succeeded in finding the organism—if it be an organism—which causes rabies. Hence it cannot be cultivated on gelatine in test-tubes, and no modified culture of bacteria can be produced, as is now done in the case of diphtheria and other diseases. Other means had to be devised. After countless experiments it became evident that, if the spinal cord of a hydrophobic rabbit be kept dry at a temperature of 25° C. for a couple of weeks, the strength of the virus has so far vanished that, if an emulsion of the cord be injected, it produces no rabies but has only a slight vaccinating effect. If two days later an emulsion of a twelve-days-old spinal cord be injected, the vaccinating effect is stronger; but the body, already inured to slight doses of the poison, remains unaffected. Thus, by gradually increasing the strength of the dose, a virus may at length be injected which would infallibly produce rabies but for the previous inoculations. When an animal is bitten by a mad dog, the poison transmitted takes some time to develope—some weeks at least, and often many months. If now the artificially introduced virus 'gets the start,' so to speak, of the naturally introduced poison, by the time the latter is at its height the animal has become gradually immunified to the specific poison and suffers little harm. The arsenic-eaters of the Tyrol afford an analogous case. They consume amounts of arsenic which would infallibly produce peripheral neuritis in men unaccustomed to such a diet.

It needed no small courage on Pasteur's part to inoculate his fellow-creatures against hydrophobia. In 1885 a boy some nine years old, from Meissengott in Alsace, was brought by his mother to the laboratory suffering from fourteen wounds inflicted by a mad dog. After long con-

sultations with his assistants and the most anxious deliberations, he consented to the inoculation of the boy. The next fortnight was a time of intense anxiety, but all went well. His second patient is commemorated by the bronze statue which ornaments the front of the Pasteur Institute in Paris. It represents the struggle between a peasant boy armed only with his sabot, and a mad dog; the boy was terribly bitten, but the treatment saved his life. It is not easy to arrive at an accurate estimate of the death-rate caused by rabies; but the most careful and moderate estimates show that, before this treatment was in use, some fifteen to twenty out of every hundred persons bitten by mad dogs died a most painful and horrible death. During the last fourteen years, over 23,000 persons known to have been bitten by rabid dogs have been inoculated at the Pasteur Institute; and their average mortality has been 0·4 per cent. In 1899, the latest year for which statistics are available, 1614 cases were treated, with a mortality of 0·25 per cent. Of these 1506 were French and 108 were foreigners. Of the 108 foreigners, 12 came from Great Britain and 62 from British India. It is little short of a national disgrace that we should still be dependent on French aid to succour those amongst us who are so unfortunate as to be bitten by a mad dog; but the nation which gave the use of anæsthetics to the world, and which first showed the value of antiseptics, is largely dependent to-day on foreign aid in dealing with great outbreaks of all sorts of diseases within its borders. The German Koch and the Russian Haffkine are called in to cope with the cholera in India; we fall back upon the Swiss Yersin and the Japanese Kitasato to elucidate the true nature of plague, and to devise methods for combating its ravages. When rinderpest breaks out in South Africa it is again to Koch that we turn. The unsatisfactory position of Great Britain in these matters is to some extent due to a small but active section of society whose affection for their lap-dogs has overpowered their sense of duty to their neighbours. It is, however, we fear, still more due to the unintelligent treatment of men of science by the Government of the country, and to the want of appreciation of the value of science shown by society at large. If, to balance the list given a few lines above, we recall the work of our country-

man, Major Ross, on the malarial parasite, it serves only to remind us of the difficulties placed in the way of his research by the officials of the service to which he belonged and the slightness of the recognition which he has received from the Government.

In 1874 the French National Assembly voted Pasteur, as some recognition of his work on sericulture, a pension of 12,000 francs a year; nine years later this was increased to 25,000 francs, and it was further agreed that the pension should be continued to his wife and children. In 1881 he was nominated to represent France at the International Medical Congress which met that year in London. The reception accorded him when, with his host, Sir James Paget, he mounted the platform in St James's Hall, overwhelmed him. 'C'est sans doute le prince de Galles qui arrive,' he remarked to his host, never dreaming that such acclamations could be meant for him. The following year he succeeded to Littré's fauteuil at the Academy. In 1888 the President of the Republic opened the Pasteur Institute, which had been erected and endowed by a public subscription from all countries and from all classes; and there in 1892 he received a distinguished collection of scientific men, who had come from all parts of the world to congratulate him on his seventieth birthday.

Three years later his health began rapidly to fail. Two strokes of paralysis followed one another at a short interval, and on the 28th of September, 1895, he died. He lies buried in the Institute he loved so well. A nobler monument, or one more worthy of him who lies therein, has never been erected by man. The benefits which his simple, strenuous, hard-working, noble life conferred on humanity cannot be estimated. They help us, however, to realise the truth of the old Arabian proverb, 'The ink of science is more precious than the blood of the martyrs.'

M. Vallery-Radot has given what will probably prove to be the definitive Life of Pasteur. He has written at length and he has written well. That he is not a man of strict scientific training in no way detracts from the merit of the work; rather, in many respects, this makes the book more readable. The pupils of Pasteur, who are now carrying on his work, have, out of the abundance of their knowledge, helped in the more technical portions of the book; whilst M. Vallery-Radot, from his intimacy and relationship with

the subject of his biography, has been able to supply those personal details which form so essential and so interesting a part of every good biography.

For one who knew Pasteur only during the last decade of his life, to attempt any account of his character may savour of impertinence. Still it is impossible to close this article without some tribute to his simple dignity of manner, and above all to his infinite kindness. No man has done more to lessen suffering in this world, both in man and the lower animals; and probably but few have felt so much sympathy with suffering in others. As a boy—and French country boys are not more thoughtful about the suffering of animals than those of other races—he refused to go shooting. 'La vue d'une alouette blessée lui faisait mal.' As an old man, it was a touching sight to see him amongst the sufferers under treatment at the Institut Pasteur, patting the little children on the head, heartening up the timid and giving *sous* to the brave, infinitely tender to the frightened mothers. Another dominating trait in his character was his unflinching desire for truth; to 'prove all things' and to 'hold fast that which is good' was the motto of his working life. His success was in no small measure due to the rigorous tests he applied at all stages of his investigations; it was also due to the untiring assiduity with which he worked, never sparing himself, never in any way thinking of himself. But above all it was due to the intense thought he bestowed upon his researches. Concentrating his intellect upon the problem in question he thought out all possible solutions, and was prepared for all possible eventualities. It was this power of thought, coupled with a matchless gift of observation and experiment, that enabled him to leave a name which cannot be forgotten whilst civilisation endures.

Art. V.—NAVY BOILERS.

1. *Water-Tube Boilers.* By J. A. Normand. London: The Bedford Press, 1895.
2. *Marine Boilers: their Construction and Working.* By L. E. Bertin, Chief Constructor of the French Navy. Translated and edited by L. G. Robertson. With Preface by Sir W. White. London: John Murray, 1898.
3. *On the Boiler Arrangements of certain recent Cruisers.* By F. T. Marshall. London: The Institution of Naval Architects, 1899.
4. *Memorandum respecting Water-Tube Boilers in H.M.'s Ships.* (Cd. 250.) London: Eyre and Spottiswoode, 1900.
5. *Les Nouveaux Générateurs Belleville.* By M. Godard. Paris: Imprimerie Chaix, 1900.
6. *Interim Report of the Committee appointed . . . to consider . . . modern types of Boilers for naval purposes.* (Cd. 503.) 1901.

Our purpose in writing this article is to give a concise account of the problems which concern Navy boilers, with particular reference to the water-tube types. The subject is one of national importance, yet few outside professional circles have any clear knowledge of the subject. It is regarded as one which wholly concerns experts, who are also known to be divided in opinion concerning the choice of the most suitable boiler, or boilers, for the service of the British Navy. Hence a feeling of uneasiness has arisen—a fear that when the supreme hour of national trial arrives the Navy boilers may break down, and leave cruisers, battleships, torpedo-boats, and destroyers, at the mercy of a more alert foe.

The real truth cannot be gathered from conflicting statements made in Parliament and in the Press, for these are too often of an entirely irresponsible and hearsay character. The literature of water-tube boilers is in its infancy, and information about them is mostly scattered in the pages of technical journals. For this reason the treatise of M. L. E. Bertin, who is an expert of much experience, must remain the standard work for several years to come. It embodies substantially all the information which is available on this subject down to the present time. The original work was published in Paris in 1896.